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1. Your reference — KJB/MM/RL/P43792

2. Patent application number *(The Patent Office will fill in this part)* — **9916740.5** — 17 JUL 1999

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

   UNIVERSITY OF WARWICK
   COVENTRY
   CV4 7AL

   Patents ADP number *(if you know it)* — 798553001

   If the applicant is a corporate body, give the country/state of its incorporation

4. Title of the invention — GAS INJECTION MOULDING WETHOD AND APPARATUS

5. Name of your agent *(if you have one)*

   "Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

   WITHERS & ROGERS
   GOLDINGS HOUSE
   2 HAYS LANE
   LONDON SE1 2HW

   Patents ADP number *(if you know it)* — 1776001

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Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*
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7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application	Date of filing *(day / month / year)*
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8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*
   a) any applicant named in part 3 is not an inventor, or
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Continuation sheets of this form	
Description	9
Claim*(s)*	–
Abstract	–
Drawing*(s)*	6 +6

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Priority documents	–
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Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	–
Request for preliminary examination and search *(Patents Form 9/77)*	–
Request for substantive examination *(Patents Form 10/77)*	–
Any other documents *(please specify)*	–

11. I/We request the grant of a patent on the basis of this application.

Signature .... Date 16 July 99

WITHERS & ROGERS

12. Name and daytime telephone number of person to contact in the United Kingdom — KARL BARNFATHER 0121 233 2997

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Gas Injection Moulding Method and Apparatus

This invention relates to an improved method and apparatus for gas injection moulding.

In conventional gas assisted or gas injection moulding methods, melt material is first injected into a mould. The melt, which may be a polymer or other suitable material, is then forced against the interior of the mould using injected gas within the melt. The melt and mould are then allowed to cool so that the melt hardens forming the injected moulding product, this cooling stage being by far the longest part of the injection moulding cycle. Minimisation of this cooling stage is extremely important, as it has a major influence on the reduction of the overall injection moulding time. This also has capital benefits in reducing manufacturing costs.

It is an object of the present invention to provide an improved method of, and apparatus for, gas injection moulding.

According to one aspect of the invention there is a method of gas injection moulding comprising injecting a melt into a mould and injecting gas into the melt to form a gas cavity in the melt, wherein the injection gas is cooled preferably to below the external ambient air temperature before being injected into the melt.

According to another aspect of the invention, there is a gas injection moulding method comprising injecting a melt into a mould and injecting gas into the melt to form a gas cavity in the melt, utilising injection gas having a temperature lower than that of ambient air temperature.

According to a further aspect of the invention, there is a gas injection moulding method using a mould having a melt inlet aperture, gas inlet aperture and gas outlet aperture, comprising the following stages:

(a) injecting a melt into the mould;
(b) injecting gas from the inlet aperture in the mould into the melt to form a gas cavity within the melt;
(c) forming a gas channel between the gas cavity and the gas outlet aperture in the mould and
(d) providing gas flow through the cavity between the gas inlet and outlet apertures.

According to another aspect of the invention, there is provided a gas injection moulding method wherein a mould is provided comprising gas inlet and gas outlet apertures and the method includes the step of flowing the injection gas between the gas inlet and outlet apertures in use.

Preferably, the injection gas is nitrogen. The temperature of the injected gas may be in the range 0°C to -176 °C, preferably in the range -10 °C to -50 °C, and most preferably about -25 °C. The pressure of the gas in the mould can be in the range 10 to 350 bar.

According to yet another aspect of the invention, there is provided apparatus for gas injection moulding comprising a mould having inlet apertures for the ingress of gas and melt material into the mould, wherein, melt material is injected into the mould and gas is injected into the melt material to form a gas cavity in the melt, and wherein gas having a temperature lower than the ambient air temperature is used as the injection gas.

According to a yet further aspect of the invention, there is provided an apparatus for gas injection moulding comprising a mould having inlet apertures for

the ingress of gas melt material into the mould, and outlet apertures for the egress of gas and melt from the mould, and wherein use of the apparatus comprises the following stages:

(a) injecting a melt into the mould;

(b) injecting gas from an inlet aperture in the mould into the melt to form a gas cavity within the melt;

(c) forming a gas channel between the gas cavity and a gas outlet aperture in the mould and

(d) providing gas flow through the cavity between the gas inlet and outlet apertures

Alternatively the channel between the gas cavity and the outlet aperture is formed by forcing a stream of gas from the outlet aperture toward the cavity. Preferably, the channel between the gas cavity and the outlet aperture may be formed by perforating the melt using a moveable needle at the outlet aperture.

The gas injection moulding apparatus may comprise a heat exchanger to cool the injection gas prior to injection into the mould. This heat exchanger may comprise a coiled portion of piping, through which injection gas flows, and this coiled portion of piping may be immersed in a liquid having a lower temperature than that of the gas, so cooling the gas. The cooling liquid could be, for example, liquid nitrogen.

The injection gas may be at a lower temperature than the ambient air temperature and/or may be nitrogen. As before, the temperature of the injection gas may be in the range 0 °C to -176 °C, preferably in the range -10 °C to -50 °C, and more preferably around -25 °C.

The gas may enter or exit the mould by means of injection needles. A further aspect of the invention is a gas injection needle comprising a first part defining a gas channel and a movable member that can extend beyond the first part thereby to extend the gas channel. Preferably, the moveable member is located coaxially within the gas channel, and the moveable member preferably is elongate and movable axially within the gas channel. Most preferably, the movable member is displaced to extend beyond the end of the gas channel.

Gas injection moulding apparatus in accordance with the invention will now be described, by way of example only, with reference to the following drawings in which:

Figure 1 is a schematic diagram of a gas injection moulding system for use in accordance with the invention;

Figure 2 (a) and (b) show two method stages of gas injection moulding in accordance with one aspect of the invention;

Figure 3 (a), (b) and (c) show three method stages of gas injection moulding in accordance with another aspect of the invention;

Figure 4 (a), (b), and (c) presents a flow diagram summarising alternative process stages of gas injection moulding methods in accordance with the invention;

Figure 5 is an exploded view of a gas injection needle used in a further aspect of the invention and

Figure 6, (a) and (b) show two operational states of a gas injection needle according to a further aspect of the invention.

Referring to figure 1, a gas injection moulding system 1 comprises gas injection moulding apparatus 10 and associated process control equipment. Moulding apparatus 10 comprises a mould 12, which may be a two part type mould or any other type known in the art, that defines a mould cavity 14. Melt material 16 is injected into the mould cavity 14 from a melt reservoir 18, and via a melt inlet aperture 20. A gas inlet aperture 22, which may comprise an injection needle 24, allows injection of gas 26 into the melt 16. A corresponding gas outlet 28 which can comprise needle 30 may also be provided, as well as an outlet 32 for the melt.

Associated process control equipment is provided to control the ingress and egress of gas and melt to and from the mould cavity 14. Injection gas, for example nitrogen, is supplied by gas injection equipment 34 comprising a gas generation unit 36 and gas pressure control module 38, the pressure control module 38 being controlled by a set point input handle 40. In one aspect of the invention, the injection gas line may comprise a heat exchanger 42 to cool the gas prior to its injection into the mould cavity 14 and the heat exchanger may comprise a coil 44 immersed in a cooling material such as liquid nitrogen. In a further aspect of the invention the gas injection needles 24 and/or 30 may be movable (as described later) and in this case are actuated by, for example, an actuator 46 controlled by a controller 48 as shown for needle 24. A controller 48 may also be used to control other aspects such as the gas injection equipment 34 and the heat exchanger 44, as well as various process valves shown at a, b and c for example. It may be possible to recycle the injected gas once it has passed through the mould as shown by a process stage d. However, this may not be an advantage as the injection gas is readily available and re-circulation of the gas can cause contamination in the gas stream by the melt material.

Referring to Figure 2, parts a and b, there are shown two steps in a gas injection moulding method according to a first aspect of the invention. In Figure 2a, a first stage of the moulding process is shown wherein a melt material 16 is injected

into cavity 14 in mould 12 via aperture 20 from a melt reservoir 18. (For simplicity in this case the process valves are not shown). Figure 2b shows the later gas injection stage of the method where gas such as nitrogen is injected through aperture 22 to form a gas cavity 26 inside the melt material. Once the gas cavity has dispersed the melt into all corners of the mould the pressure is held at a pre-set level until the melt cools and hardens. In one aspect of the present invention, the injected gas 26 is cooled to below the ambient air temperature outside the mould prior to being injected into the mould, for example by means of heat exchanger coil 44. Before injection into mould 12, the gas is preferably cooled to between 0°c and -176°C. Within this range a preferable temperature for the gas is about -25 °C. Once the melt is sufficiently dispersed, the cooled gas is held at a static pressure and thermal energy passes from the hot melt into the cooled gas, thereby providing a greater temperature gradient than if gas at ambient temperature were used, and so speeding up the cooling process.

Turning to Figure 3, a gas injection moulding process according to a further aspect of the invention is shown. Parts a and b of Figure 3 generally correspond to the equivalent parts to Figure 2 but, in this case, an additional process stage is shown at c. Between process stages b and c, a channel 31 (see Figure 3c) is formed that allows gas flow from the gas cavity 26 within the melt material 16 to a gas outlet 28, which again may be in the form of a needle 30. This allows circulation of the injection gas through the cavity 26 formed between the inlet 22 and the outlet 28 as shown by the direction arrows in Figure 3c. By circulating the gas, greater heat transfer between the hot melt and the circulating gas is achieved and so the cooling time again is reduced. An even greater reduction in cooling time is achieved if cooled gas is used as in the static process already described for Figure 2 a and b.

Figure 4 summarises three aspects of the invention in a flow diagram. In figure 4a the process stages of the static or 'no-flow' process for example, using a single gas inlet, are shown. Low temperature gas such as nitrogen is used but it is

not circulated once it has entered the mould and it is held at a static pressure. In this case heat exchange between the melt, the mould and the gas takes place by conduction between the melt and the mould as well as convection between the static gas and the melt. Parts b and c of Figure 4 show flow diagrams for a case where gas flows through the mould once the melt has been dispersed, i.e. as already shown schematically in Figure 3 earlier. In both cases a multiple needle aperture or injection system is needed with apertures to allow gas to both enter and exit the gas cavity and circulate to remove heat from the melt.

In the process where gas circulates in and out of the mould, a method is needed to form the channel 31 between the gas cavity and an outlet aperture, for example between the gas cavity 26 and outlet aperture 28 shown in Figure 3. There are several ways of achieving this, according to the gas bubble length and type of needle used.

If the gas bubble length is sufficient to reach the second needle position (e.g needle 30 in Figure 3c), then the (thin) layer of material covering this needle can be removed by the use of high pressure gas injected through this needle (30). Alternatively, in the event of a greater thickness of material covering the second, or outlet needle, a channel can be formed by injecting a reverse flow of gas at this second needle, or a movable needle can be used, as described below.

Figures 5 and 6 show a gas injection needle that can be used in the apparatus of the invention. Referring to figure 5, a retractable or movable venting needle 50 is shown, comprising a needle body 52 and a gas channel or needle sleeve 54. Channel 54 is connected to body 52 via an annular attachment 56. A movable central needle member or pin 58 is located co-axially within sleeve 54. In use, channel 54 directs gas to or from the melt. Pin 58 has a groove 59 and a conical end portion 60. Pin 58 can move axially out or in channel or sleeve 54 as shown by the double headed arrow. The body 52 of the needle device may have planar surfaces

62 to allow easy location within moulding apparatus, and respective gas inlets and gas outlets shown at 64a and 64b. Pressurised gas enters at inlet 64a, forcing pin member 58 outward and allowing gas flow from the needle. Body 52 may also comprise a notch 65, again to allow easy location of the body in a mould. A chamber or cavity 66 houses further components of the device. These components are held in position by screws 70 that pass through apertures 72 in a lid 74 of the device. The lid contains a seal 76 having screw holes 78, an o' ring seal 80, a plunger 82, a spring member, for example a coil spring 84 and a limiting sleeve 86. The limiting sleeve 86 serves to control axial displacement of pin member 58 and pin member 58 is attached to plunger 82.

Figure 6 a and b show the function of the pin member 58 within channel 54 in more detail. As can be seen from the figure, the end 60 of memeber 58 comprises a front planar surface 90 and a tapered conical surface 88. The tapered conical surface 88 allows easy location of end 60 against channel sleeve 54. Figure 6a shows the situation where pin 58 is located within channel 54, that is, the case where there is no gas flow and the melt material can build up over the end of needle. In Figure 6b a later stage is shown where pin 58 has moved outward in the direction of arrow I and gas flow is allowed in direction of arrows II . The outward movement of the pin 58 causes its end 60 to rupture the melt layer around it forming a channel between the outlet and the gas cavity in the melt. Thus, the movable needle shown in figures 5 and 6 can be used for example as needle 30 in Figure 3 to form gas channel between the gas cavity, or bubble within the melt and a gas outlet.

As described, the invention enables reduced gas cooling times in gas injection moulding. This is achieved by the different aspects of the invention, namely (a) the use of cooled injection gas that is held statically within the mould and/or (b) the use of circulating gas that passes through the mould to take heat away convection. In this latter aspect of the invention (b), either cooled gas or gas at ambient temperature may be used and the convective effect of the moving gas leads

to greater heat transfer. Cooled gas and gas flow used in combination as described in Figure 4 provide the greatest reduction in mould cooling time.

1/6

FIGURE 1

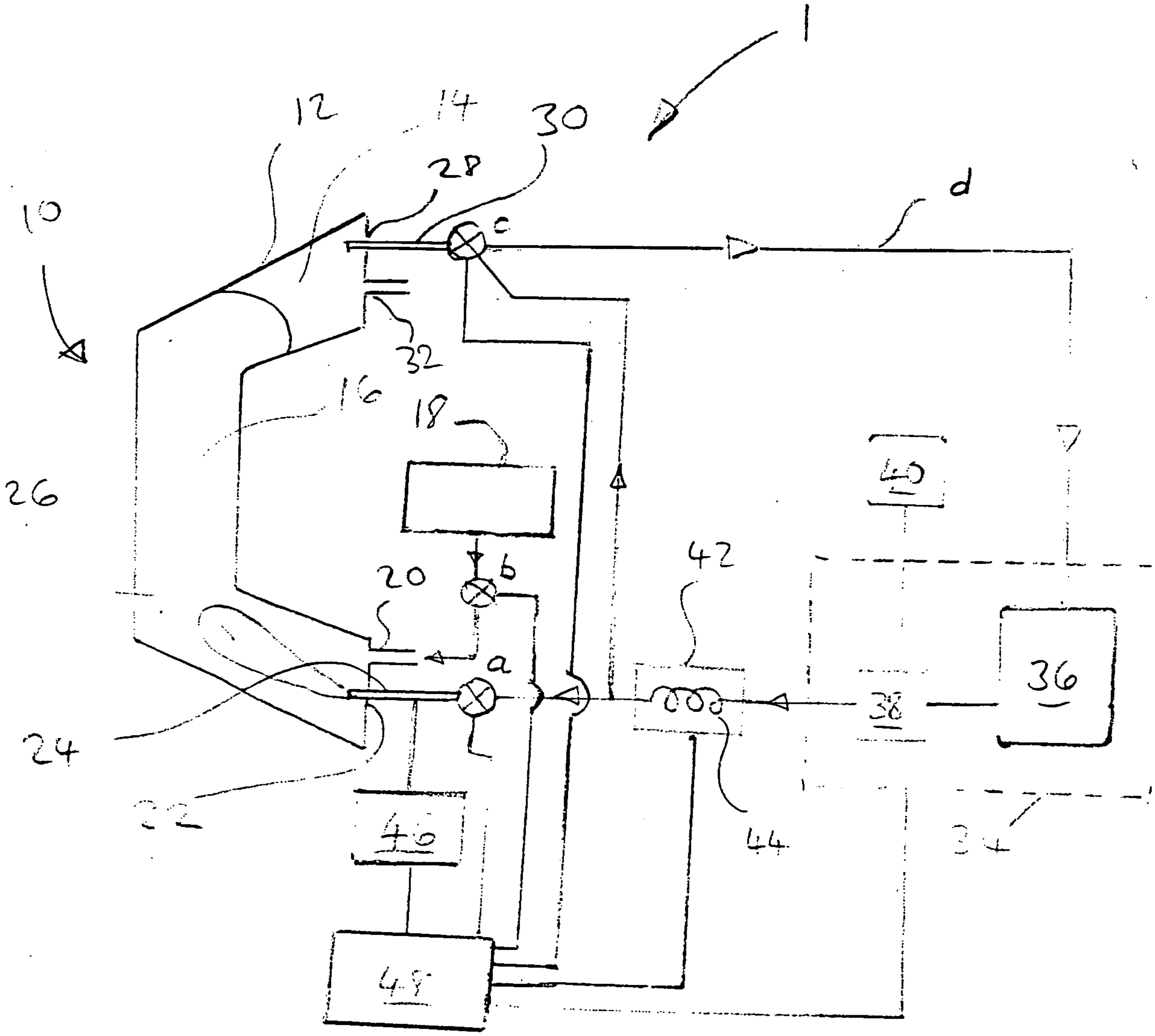
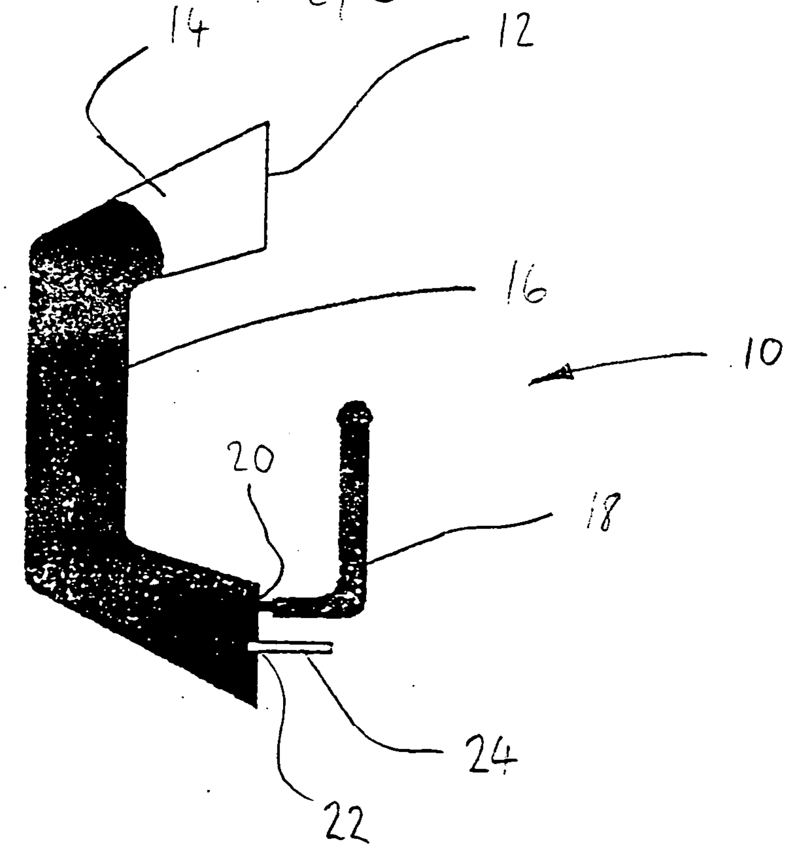


FIGURE 2

(a)



(b)

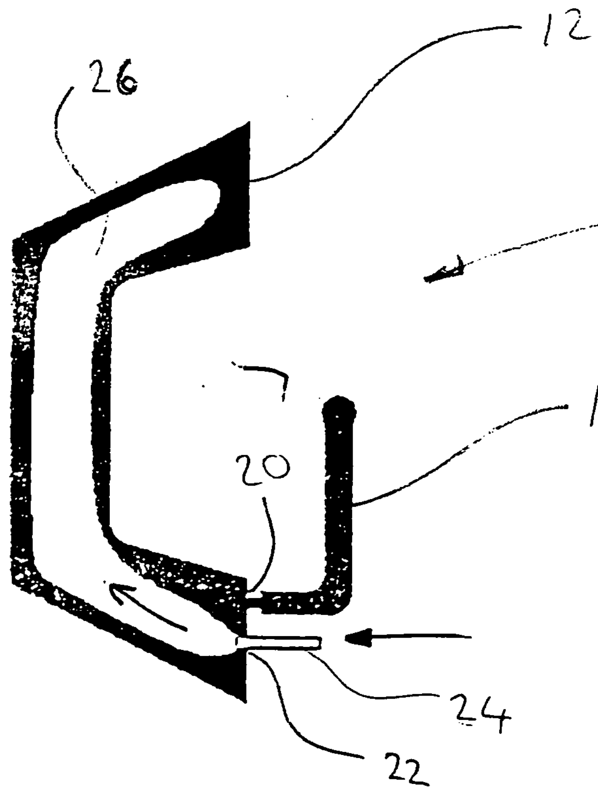


FIGURE 3

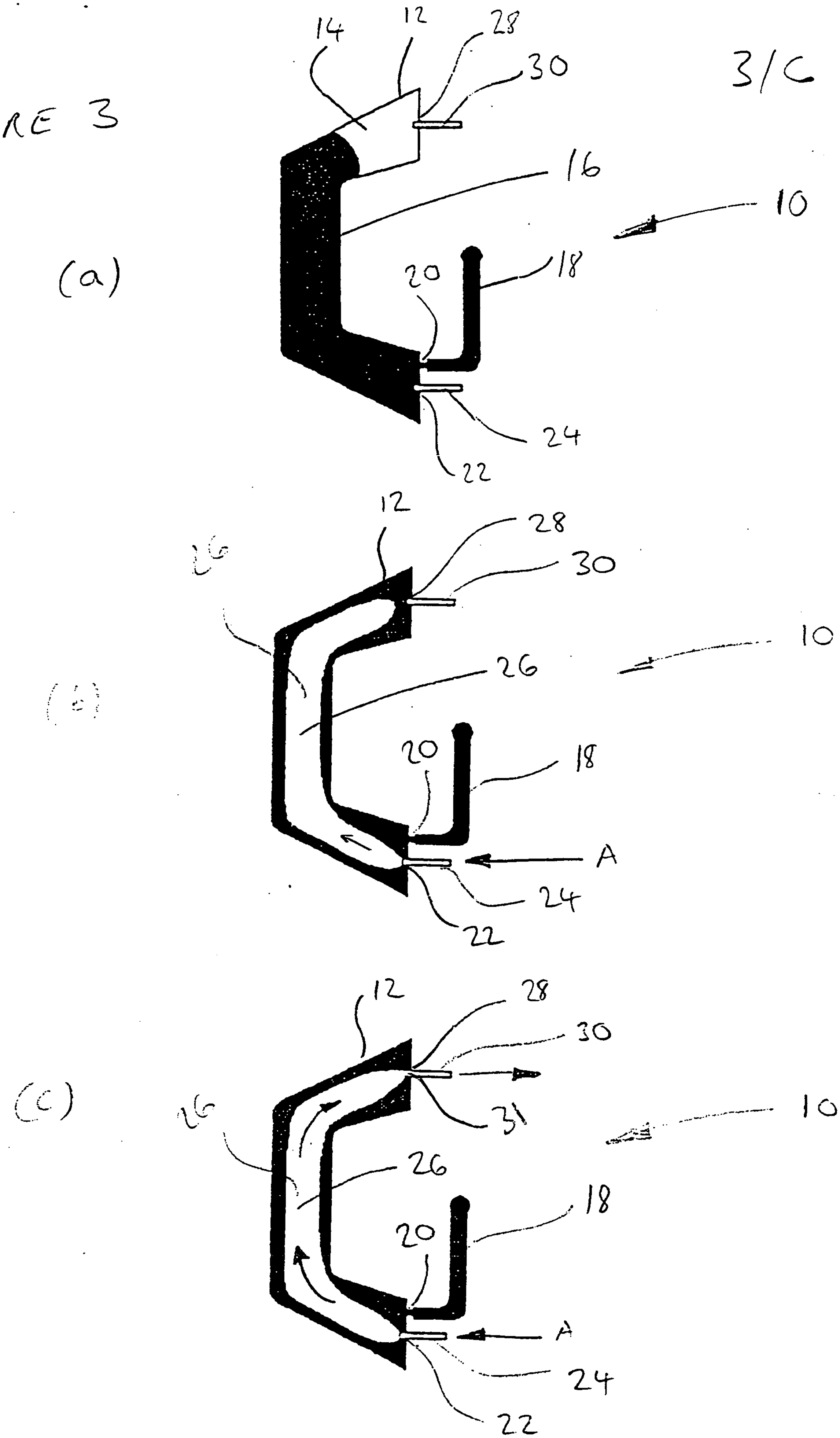
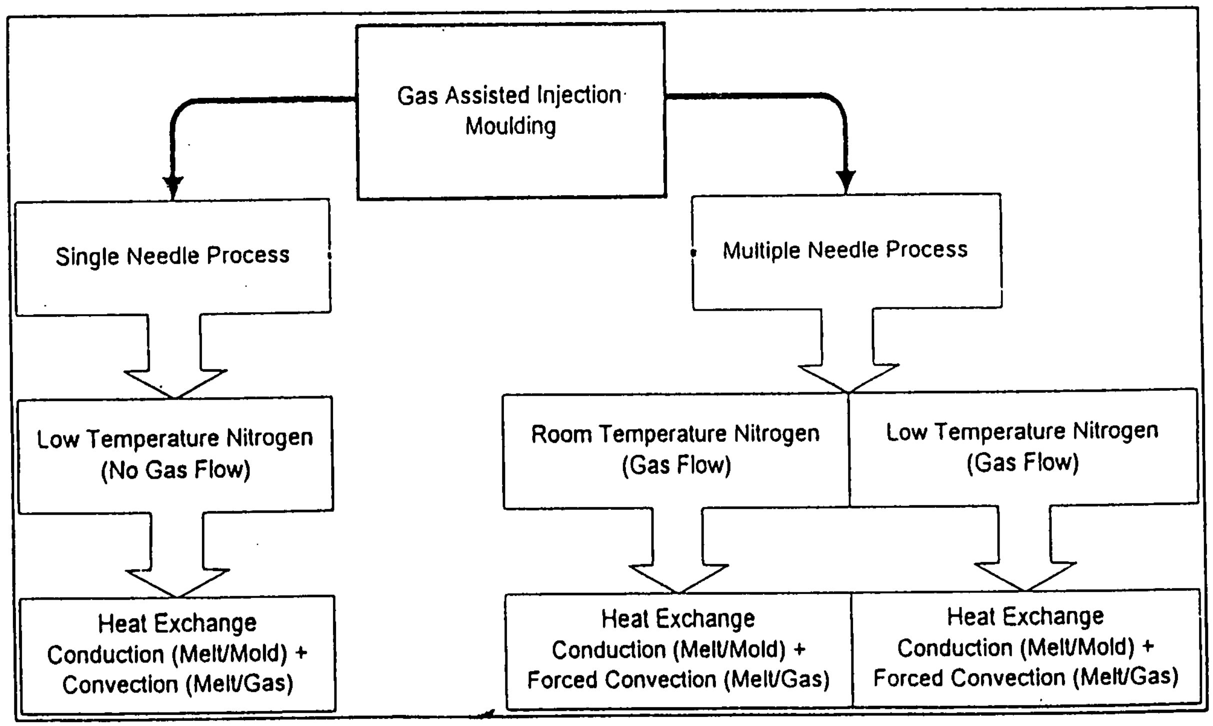

(a)
14
12
28
30
16
10
18
20
24
22
(b)
12
28
26
30
10
26
20
18
A
24
22
(c)
12
28
30
31
26
10
26
18
20
A
24
22

FIGURE 4


Gas Assisted Injection Moulding
Single Needle Process
Multiple Needle Process
Low Temperature Nitrogen (No Gas Flow)
Room Temperature Nitrogen (Gas Flow)
Low Temperature Nitrogen (Gas Flow)
Heat Exchange Conduction (Melt/Mold) + Convection (Melt/Gas)
Heat Exchange Conduction (Melt/Mold) + Forced Convection (Melt/Gas)
Heat Exchange Conduction (Melt/Mold) + Forced Convection (Melt/Gas)

(a) (b) (c)

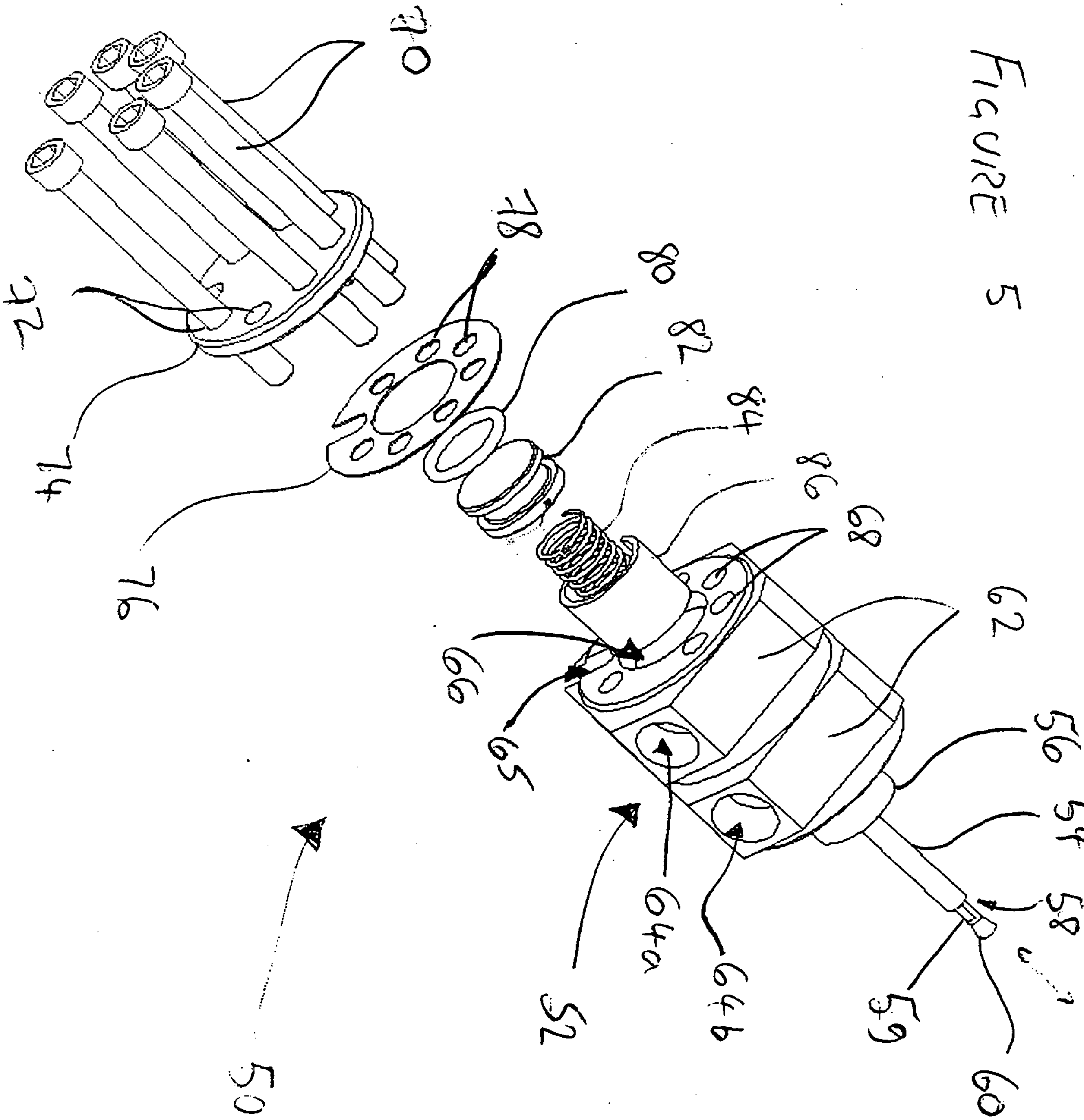
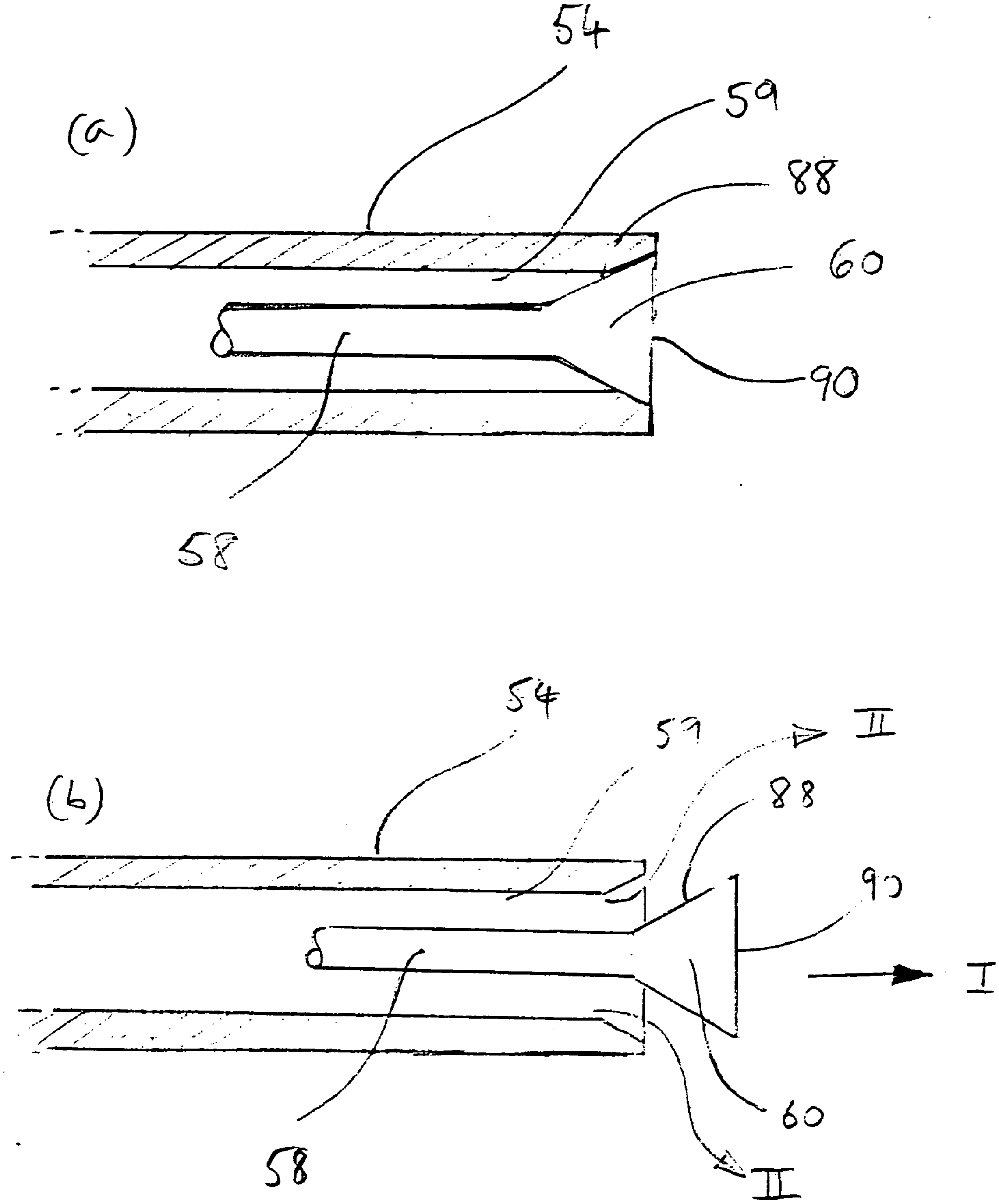


FIGURE 5

FIGURE 6



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